The University of New Hampshire Center of Excellence for Coastal Ocean Observation and Analysis

Semi-Annual Technical Report: NA16OC2740
Period of Performance: August 2004 – January 2005

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The Coastal Observing Center at UNH (sometimes called COOA) is working to develop and implement an observing system for monitoring the Western Gulf of Maine ecosystem. Our goal is to implement an end-to-end system with the capability to detect, model, and ultimately forecast changes in the ecosystem. The Center is developing new and efficient methods to acquire, manage and distribute data. Data are analyzed and synthesized to generate new information, and information products are being designed to meet the needs of stakeholders. Two stakeholder communities identified in this region are those interested in water quality and in the fate and variability of the near-shore fisheries. A third stakeholder community are the formal and informal educators who help us translate knowledge about the coastal ocean to current and future generations. We are working closely with the Gulf of Maine Ocean Observing System (GoMOOS) and other partners in the northeast. Our *collective* goal is to establish a sustainable program of coastal ocean observations as part of the U.S. Integrated Ocean Observing System.

The Coastal Observing Center was established in 2002 to draw upon the talents of UNH scientists with expertise related to coastal observing and analysis. GoMOOS had established an array of 10 buoys in 2001 that provided real-time observations of the physical environment (currents, temperature, winds). While such measurements are essential to an ecosystem monitoring program, there was a need to develop new methodologies, models and analyses that pertain directly to the ecosystem.

Our focus is on a region centered on the Piscataqua River at Portsmouth Harbor, that extends north to the Kennebec River and south to Cape Cod (Fig. 1). This region includes Jeffrey's Ledge, one of the most important fish habitats in the Gulf of Maine, now closed to ground fishing, and the adjacent deep waters of Wilkinson Basin. Like other coastal environments, this is a region of significant biological productivity and complex circulation. This east-coast site also represents a region where the surface waters interact with advected continental air that is often polluted. The effects of air-sea exchange of such trace chemicals on any coastal ecosystem are largely unknown. Two phenomena that are likely to have a measurable impact on our oceanic ecosystem are short-term episodic events, such as storms and strong freshwater pulses from land, and the long-term deposition of trace chemicals via the air or rivers. These issues are being examined by our ship-based measurement program whose goal is to provide both an ecosystem baseline and knowledge about its variability and controls. This knowledge will inform models that will be used to simulate what we observe, and to test hypotheses about the mechanisms controlling the marine ecosystem in this region.

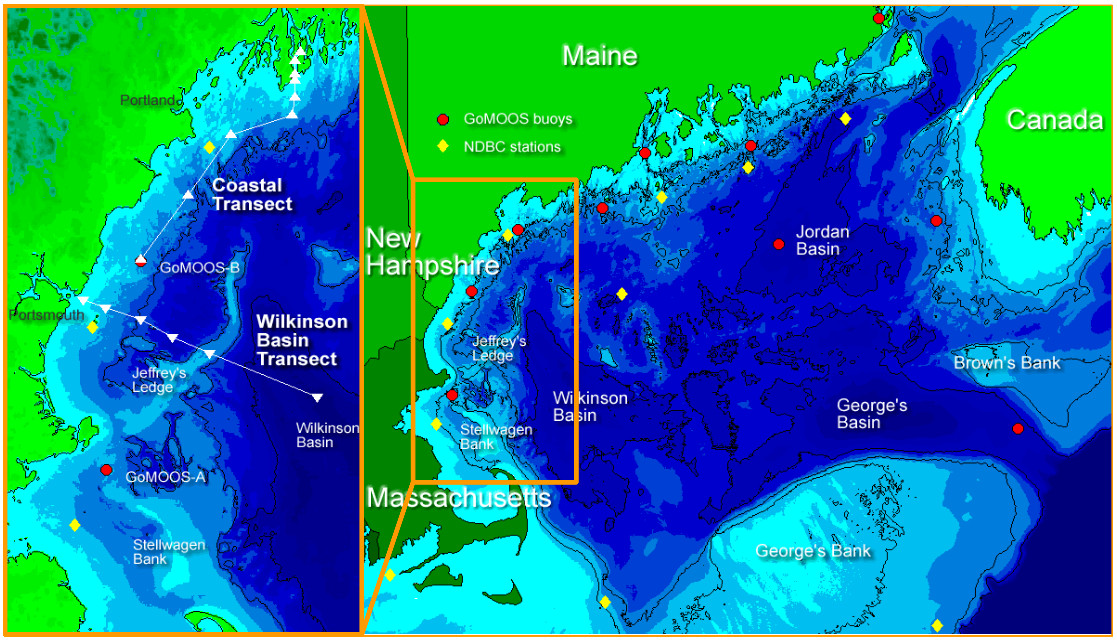

Fig. 1. The Western Gulf of Maine region of interest (left) and its location within the Gulf of Maine. Stations on the Coastal Transect and Wilkinson Basin Transect are sampled once a month. The locations of GoMOOS buoys and NDBC stations are also shown.

Field measurements are made on monthly cruises along the two transects shown in figure 1. The *Coastal Transect* visits GoMOOS buoy B and waters of the Kennebec River Estuary, and the *Wilkinson Basin Transect* extends into one of the deep basins of the Gulf of Maine. The observations are made by teams responsible for different components of the ecosystem and its environmental controls. All teams participate in the cruises. Data from the cruises flow into WebCOAST, our data management system, and are being used to create models and to develop remote sensing algorithms for our region of interest.

While much can be learned from standard oceanographic measurements of temperature, salinity, nutrients, and biomass concentrations of phytoplankton and zooplankton, new technologies are being developed for observing the ecosystem. Measurements of the underwater light field are made with state-of-the-art instruments and used to calculate concentrations of phytoplankton biomass (as chlorophyll) as well as other forms of organic matter. A further step being taken is to connect our observations to satellite remote sensing of surface winds, ocean color and sea surface temperature to develop cost-effective means to extend such observations in time and space. Our long-term plan is to minimize the need for ship-based sampling by developing automated techniques deployed on buoys and by using remote sensing methods. However, the ability to sample and assess biological and ecological variables currently requires water sampling with analyses conducted in the laboratory.

An observing system for monitoring the ecosystem is approached by posing five questions: How is the ecosystem changing? What are the forcing factors causing it to change? How does the ecosystem respond to natural and human forcings? Can we predict future changes? and What are the consequences for stakeholders in our region?

How is the Ecosystem Changing and Why?

We know from historical records and from our own observations that the timing and magnitude of phytoplankton blooms vary significantly on interannual to decadal time scales (Fig. 2). In some years (e.g., 2002), the spring bloom of phytoplankton occurs in April, coinciding with vernal flowering on land, whereas in other years (e.g.,1999), the bloom occurs in February
(Durbin *et al*. 2003).

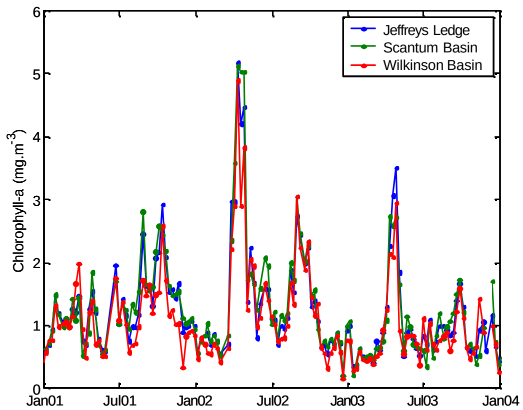

Fig. 2 – Time series of surface chlorophyll concentrations at three sites in the Western Gulf of Maine derived from MODIS Terra data (2001-2003).

Continuous Plankton Recorder (CPR) data reveal that this late-winter bloom was present throughout the 1990s but was, from all indications, absent during the 1980s. The CPR data have also shown dramatic shifts in the abundance of prominent zooplankton species over the past four decades (Pershing *et al*. 2004). Four of the smaller taxa were 1-3 orders of magnitude more abundant in the 1990s than in the 1980s, whereas adults of *Calanus finmarchicus* experienced a 1-2 order of magnitude decline in the 1990s.

Calanus finmarchicus is the major prey of forage and other species, including herring, mackerel, sand lance, and right whales. In the Gulf of Maine, *Calanus finmarchicus* is at the southern edge of its temperature range, and thus is vulnerable to climate-mediated changes in water temperature. During the plankton surveys conducted by Henry Bigelow in the early 1900s (Bigelow, 1926), *Calanus finmarchicus* was observed to dominate the zooplankton assemblages. However, in recent years, its abundance has declined in several areas within the Gulf of Maine. Such changes have been linked to reduced calving rates and migration patterns of right whales, and to the disappearance of hundreds of thousands of red-necked phalaropes (right) over the past decade in the Bay of Fundy.

Interannual variation in zooplankton species might be the result of changes in climate. The *upward trend in northern hemisphere atmospheric temperature*, attributed to the increase in atmospheric greenhouse gases, might result in a warming of Gulf of Maine surface waters. Recent warming trends have been seen in surface waters in Boothbay Harbor, for example, and in the long records from the dock at Woods Hole. Temperature change in itself may gradually or abruptly alter species distributions, as some species, such as herring and *Calanus*, are at the southern edge of their range. Another climate-related reason for interannual variation in the ecosystem might be the nature of water that enters the Gulf through the Northeast Channel. The *North Atlantic Oscillation* (NAO)[1] is a climate-related phenomenon that affects Arctic wind patterns and water temperature in the coastal Northwest Atlantic, where it has been shown to affect the northern cod stock (Drinkwater 2002). The influence of the NAO on the Gulf of Maine is less clear, although there is evidence that in some states relatively cold and *Calanus*-poor Labrador shelf water flows southward across the Northeast Channel, where it makes its way into the deep water of the Gulf of Maine. *Interannual to interdecadal variations in wind patterns, circulation and stratification* also force ecosystem change in the Gulf of Maine.

Effects of Rivers on the Western Gulf of Maine Ecosystem. -- One of the ways that humans affect the marine ecosystem is through the rivers. Large rivers are major mechanisms for nutrient delivery to the ocean, and river water quality affects freshwater ecosystems and oceanic food webs. Three rivers are important to the Western Gulf of Maine Ecosystem. The Kennebec River estuary lies at the northern edge of our study area and has been a focus of our field work for the past two years. Discharge from this estuary mixes with the western Maine coastal current and is carried southward, thus potentially affecting water conditions throughout the region. The Kennebec River estuary is formed by the convergence of the Kennebec and Androscoggin rivers. The Androscoggin River was designated one of the ten most polluted rivers in America in the 1960s (Mitnik 2002), and both rivers have a history of water-quality problems. Numerous pulp and paper mills are located along the rivers, as well as municipal wastewater treatment facilities. Prior to the passage of the Clean Water Act in the mid-1970s, partially treated and untreated municipal and industrial wastewater was discharged directly into both rivers. Clean-up activities since that time have partially restored the Androscoggin, and both rivers now generally maintain fishable/swimmable status. The Androscoggin and Kennebec rivers have been implicated in the re-occurring blooms of "red tide" organisms, although the exact linkage remains unclear.

Two other rivers important to the Western Gulf of Maine region are the Piscataqua and Merrimack rivers. The Piscataqua River enters the Gulf of Maine at Portmouth Harbor, one of only two naturally deep harbors on the U.S. east coast.[2] Together with Little Bay and Great Bay, it forms the Great Bay Estuary, a large, inland, tidally-dominated system that serves as a critical breeding and nursery ground for finfish, shellfish and invertebrates. Significant reductions in water quality and seagrass in this estuary have been linked to increased development since the 1970s (Short *et al*. 1991). The Merrimack River enters the Gulf at Ipswich Bay, Massachusetts. It has the most densely populated drainage basin in our domain. Many of New England's former mill cities (Manchester, Lawrence, Lowell, Haverhill) are located along this river, which has a long history of pollution issues. Of this river Henry David Thoreau (1849) wrote "*Salmon, shad and Alewives were formerly abundant here . . . until the dam, . . . and the factories at Lowell, put an end to their migrations hitherward. . . . Perchance, after a few thousands of years, if the fishes will be patient, and pass their summers elsewhere . . . nature will have levelled . . . the Lowell factories, and … River [will] run clear again.*"

[1] The NAO is an index of the difference in the winter surface air pressure of a low pressure system off Iceland and a high pressure system off the Azores that typically set up in the North Atlantic basin.
[2] The other is the Hampton Rhoads of Virginia. The large volume of water exchanged by tides between the Great Bay and the Gulf of Maine keeps the Portsmouth harbor deep and eliminates the need to dredge.

- **ACCOMPLISHMENTS TO DATE**

Accomplishments to date are summarized here in relation to the 18 objectives listed in last year's proposal (here shown in italics).

1. *Install autonomous sensors on fishing vessels, coastal research vessels, and ferries operating in the Gulf of Maine that acquire nearly continuous meteorological and ocean data that is broadcast to a shore-based server every hour.*

Fleetlink systems have been installed on two research vessels, the R/V Gulf Challenger and the R/V Tioga. These systems were previously deployed on fishing vessels. Links from WebCOAST to the WHOI database housing the data have been established. Progress has been slow with the implementation of these systems. As of the end of January 2005, only 81 days of data had been posted (including data from fishing vessels). We are currently evaluating the systems and the data quality.

2. *Develop a buoy that utilizes new chemical and optical sensors and wireless telemetry that can be easily deployed in an estuary to monitor water properties such as turbidity, inorganic nutrients, chlorophyll, dissolved organic carbon, and other substances.*

The coastal buoy has been designed, components ordered, and is on track for deployment in April 2005 after the winter ice clears. Design requirements were formulated in the early fall of 2004 with representatives from the UNH/NOAA Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), the Great Bay National Estuarine Research Reserve, the UNH ocean engineering department, and WetSat Inc. (a daughter company of both WetLabs Inc. and Satlantic Inc.). Comparison of available nutrient sensors is one of CICEET's current goals, and thus it was decided to refit the existing Great Bay buoy with a new YSI 9600 nitrate sensor. This meant that a new physical buoy was necessary as the original plan had been to outfit the old buoy with new systems. CICEET kindly agreed to contribute towards the ISUS nitrate sensor as part of the nutrient sensor evaluation, and the two buoys, at least initially, will be collocated to allow intercomparison. By the end of this year, there will be an end-to-end observing system in Great Bay with a well defined suite of quality-assured and controlled measurements and an established user community. The data will be made available to the Gulf of Maine Ocean Observing System through the Gulf of Maine Ocean Data Partnership which will ensure that it is ready for the Integrated Ocean Observing System.

3. *Develop a transparent anti-fouling coating that can be used with underwater optical instruments for long-term deployment in coastal waters.*

A transparent coating has been obtained with anti-fouling properties that derive from the release of a biocide (Seanine 211). The glass transition of the coating was tuned to release the biocide at a high enough flux to impart anti-fouling properties for periods greater than a month. By applying a silanization treatment, we significantly improved adhesion of the coating. This treatment was found to maintain the optical properties of the glass and to prevent delamination. Efforts to have this technology commercially developed are in progress. Initial contacts with a marine optical company were unsuccessful, but contacts with the coating manufacturer, Rohm and Haas, are promising.

4. *Develop a field sensor based on Molecular Imprinted Polymer (MIP) technology to detect saxitoxin (the HAB substance causing paralytic shellfish poisoning) in the marine environment.*

In laboratory work to date, caffeine has been used as an analyte of saxitoxin due to the intrinsic toxicity of the latter. A MIP sensing technology has been developed capable of detecting very low levels (500 ppb) of caffeine. We first developed an emulsion polymerization technique that generated MIPs which are nanoporous. That is, the sensor consists of numerous small beads (size < 100 nm) which are loosely tied together, leaving large void volumes (pores) to facilitate the transport of the analyte to the binding site. Thus, the number of binding sites is larger than in conventional MIPs, resulting in a lower detection threshold. In this setup, which is fully transportable, the detection time is on the order of a minute, and does not require any specific laboratory preparation. We expect saxitoxin MIPs to provide a very fast answer (within minutes) with light, portable equipment, allowing the detection of saxitoxin at a level comparable to the HPLC method.

5. *Develop a new underway sampling system with a comprehensive suite of flow-through seawater sensors for measuring biological, chemical and physical properties while a vessel is underway.*

A unique flow-through fast-rate equilibrator system has been acquired and has been used to make the first seasonal measurements of the surface layer pCO_2 for the Western Gulf of Maine. Our cruises include 12 coastal transects from Portsmouth to the Kennebec Estuary and two extensive river surveys of the Merrimack, Kennebec, Penobscot and Pleasant Rivers. Our suite of measurements includes CTD and optical property profiles at stations shown on figure 1, and pCO_2, oxygen, attenuation, CDOM and chlorophyll fluorescence collected between stations using the flow-through system. At each station and depth sampled, we collect water for lab analysis of alkalinity, pH, DIC, DOC, DON, nutrients, POC and absorption properties. These ship-based observations provide a baseline for how the carbon cycle works in our coastal waters and place its variability in the context of ecosystem changes.

6. *Develop a coastal carbon time-series measurement system off coastal New England to measure CO_2 gas flux at the air-sea interface together with biological and physical forcing factors.*

This effort is taking place at the Air-Sea Interaction Tower (ASIT) located 3 km south of Martha's Vineyard as part of WHOI's Martha's Vineyard Coastal Observatory (MVCO). In-water pCO_2 measurements were made using a submersible autonomous moored instrument (SAMI-CO2) for several uninterrupted periods in 2004-2005 (Feb. – Jun., Oct. – Dec., Dec. – present). Through a collaboration with H. Sosik at WHOI, dissolved oxygen and fluorometric chlorophyll and colored dissolved organic matter (CDOM) are being measured continuously at 4-m depth at the tower. These time series measurements were augmented with monthly water sampling for laboratory analysis between June 2003 and October 2004, but these are on hold now due to lack of funds. Two spatial surveys of the region have been conducted, one in June 2004 and the second in October 2004. The latter used WHOI's new R/V Tioga and made use of our Center's newly developed flow-through and vertical profiling equipment. A CIMEL robotic sun photometer (SeaPRISM) was installed on the tower and operated from February to December 2004, sending data in near-real-time to NASA's AERONET server where routine QA/QC routines were performed and data products posted on the web. The MVCO site is a coastal ocean site within the mostly land-based AERONET international sensor network. Moreover, the sensor's unique water-viewing mode makes MVCO one of only a handful of sites worldwide that routinely measure ocean color in the coastal ocean. Data management activities have begun with data being collected, archived, and formatted to facilitate delivery via WebCoast and the MVCO data systems.

7. *Develop the capability to detect, describe with coupled physical-biological models, and ultimately forecast spatial and temporal patterns in the recruitment processes of fish and invertebrate stocks in the Western Gulf of Maine.*

This is an exceedingly ambitious long-term goal that will take years to achieve. No single model or modelling approach can include all relevant processes; a hierarchy of models needs to be developed and applied according to the region and particular questions under consideration. Each type of biophysical model can be considered as a quantitative résumé of processes and interactions in one part of the pelagic ecosystem. The various components constitute a model structure, which could be called a coupled simulation system. The system integrates across coastal observing data and is a quantitative tool for the investigation of the effects of environmental variability on primary production and on the distribution and abundance of key planktonic species including the early life stages of fish and invertebrates.

We initiated a search for a postdoctoral research associate to assist in the development of the capacity at UNH to model physical-biological interactions controlling distribution and survival of larval fish and invertebrates in the western Gulf of Maine. So far this search has not been successful, although two qualified candidates were identified and offers made. At present, a third candidate has been identified and we are currently discussing a possible offer. Meanwhile, we have initiated a subcontract with Fei Chai, University of Maine, to develop an ecological model for the Gulf of Maine to be coupled to the circulation model of Huijie Xue that is supported by GoMOOS.

8. *Document, understand, and predict the seasonal progression of the planktonic assemblage in near-shore waters of the western Gulf of Maine with the ultimate goal of providing a predictive, community-based index of harmful algal blooms (HABs).*

This effort began with monthly cruises in April 2002 to sample four stations along a cross-shelf transect off Portsmouth, NH.[3] The shallow-water (40m - 100m) planktonic assemblage at these stations was analyzed to characterize seasonal patterns in this under-sampled region. Sampling at each station includes: a CTD cast, collection of water samples at up to five depths (for analysis of nutrients, chlorophyll, toxic dinoflagellates, and phytoplankton), and a vertically-stratified plankton tow using a 1/4-m Multiple Opening and Closing Net and Environmental Sensing System (MOCNESS; Wiebe et al., 1985) equipped with temperature and conductivity sensors, and 150 μm mesh nets. Two full years (to March 2004) of analysis of plankton samples, including *Alexandrium* sp. cell counts and copepod species abundances (with SS-PCR discrimination of two cryptic sibling species of *Pseudocalanus*, see Bucklin et al., 2001) were completed in September 2004, and we expect to complete the analyses of remaining samples (to August 2004) by

[3] In June 2004, this sampling program was merged with other field work. The result was that only 2 of the stations continue to be sampled. These were the ones closest and farthest from shore.

early 2005. Phytoplankton samples are awaiting analysis, while we search for needed technical expertise for this effort.

Our comprehensive multivariate analysis of the planktonic assemblage has yielded an easy-to-understand, index for the planktonic community that can be graphed in two-dimensional space. The analysis uses the multidimensional scaling (MDS) routine of the software ackage, Plymouth Routines In Multivariate Ecological Research (PRIMER; see e.g., Clarke and Warwick, 1998). This analysis has revealed a clear seasonal cycle (Manning, 2003; Manning and Bucklin, 2005), which will be used to evaluate interannual changes in this dynamic coastal region. Our winter-time nutrient data are the first of their kind for near shore waters of the western Gulf of Maine. The multivariate statistical analysis of the planktonic assemblage will also include a community-based HAB index. Data from this analysis are accessible via the Internet, with a link to the database from WebCOAST. The data are served from WHOI using the JGOFS/GLOBEC data and information management system (Groman and Wiebe, 1997). A paper has been accepted and is in press in *Marine Ecology Progress Series* based on this work (Manning and Bucklin, 2005)

9. *Develop improved remote-sensing techniques for estimating primary production and the biological and chemical composition of optically complex ("case 2") coastal waters in the Gulf of Maine.*

Significant progress has been made to establishing a sound basis for quantifying and understanding the variability in the primary productivity of the Gulf of Maine. The field sampling is allowing the parameterization of constituent relationships with optical properties as well as phytoplankton physiological properties. Satellite data processing has been significantly automated and all data are available through WebCOAST. Novel products will be brought online through active algorithm development and validation. The culmination of these efforts will be primary productivity estimates that are directly traceable to standardized techniques.

10. *Determine the effects of freshwater, nutrients, carbon and other substances delivered by rivers on net community metabolism and on the air-sea exchange of CO_2 in fluvially influenced waters of the Western Gulf of Maine.*

Water quality indices are being developed to estimate oxygen saturation and pCO_2 in the surface water of estuarine and coastal environments using optical and temperature data from the flow-through system. The strategy is to develop these indices with the potential of using satellite remote sensing data. Oxygen and pCO_2 levels reveal the trophic status of the waters sampled, that is, whether the marine community is net heterotrophic or autotrophic. Where waters are supersaturated with respect to atmospheric pCO_2 the communities are considered net heterotrophic. As expected, waters with high phytoplankton biomass are undersaturated and thus act as a sink for atmospheric pCO_2. From our river surveys, we have observed that a river can be net heterotrophic in one location and net autotrophic elsewhere, and these states change seasonally. Preliminary results were reported at the Fall AGU meeting, and further progress will be presented at the winter ASLO meeting in February.

11. Provide a single access portal to all COOA data regardless of where the data reside, with tools for searching and retrieving data catalogs and data.

Data are currently served by three different methods: (1) data are reformatted into HDF-EOS point or grid format and served directly from the WebCOAST server, (2) data are accessed from the JGOFS server at Woods Hole and served through the WebCOAST portal, and (3) data reside on the individual researcher's server and are accessed and served through the WebCOAST portal. Individual researchers can choose which of these services best fits their project's data distribution needs and capacity for processing and housing data. Data collections housed in and distributed by WebCOAST include 8-day composite MODIS SST and chlorophyll data for a large area of the western Atlantic, cruise data from the Coastal and Wilkinson Transects as well as earlier data sets (e.g., #8 above), Fleetlink data from fishing and research vessels, and time-series data measured from buoys and platforms in the Gulf of Maine.

12. Provide a portal to the JGOFS data management system at WHOI for searching and retrieving other data sets relevant to the Gulf of Maine ecosystem.

At this time, data served via JGOFS are demonstration products. We have been collaborating with Robert Groman at WHOI to develop an XML metadata representation of a suite of data served by their JGOFS system. The document will contain name-variable pairs for all metadata that are pertinent to understanding and accessing the most recent data sets, regardless of when those data were posted on-line by the data providers. Once the XML document is in place and tested, we will be able to build automatic data access connections to selected JGOFS data sets as needed. Currently, each JGOFS data set served through WebCOAST is accessed using a static URL. In order to update data, we must enter and change the URLs by hand, a labor-intensive task. The XML document will be updated regularly by automatic means at WHOI, and we will then use a web crawler from WebCOAST to determine any changes to the XML document that reflect changes or additions to JGOFS data holdings. The WebCOAST metadata catalog will be automatically updated without human intervention.

13. Acquire and host historical coastal ocean data that otherwise would not be readily accessible to the public.

At present we are not actually acquiring and hosting historical data. However, we completed a draft version of the *"Gulf of Maine Monitoring Programs"* searchable data catalog in collaboration with the Gulf of Maine Council. The goal for this activity is to link the catalog spatially (through GIS) to the WebCOAST database, and to outside data and informational resources (such as NOAA data sites), via the Internet. John Shipman, under contract to our Center, demonstrated a working version of the catalogue at the Council's Gulf of Maine Summit in St. Andrews, Canada, in October 2004. The catalogue is searchable by program name, keywords, and state name, but does not yet include the GIS or outside links capabilities. The system was enthusiastically received at the Summit.

14. Provide a node to regional, national, and global ocean observing systems.

Last year we signed a Memorandum of Understanding to form the Gulf of Maine Ocean Data Partnership. This partnership is an agreement among governmental agencies, intergovernmental organizations, academic, research, or other nonprofit entities, all engaged in the collection of data on the Gulf of Maine. Signatories agree to share data by establishing the appropriate computer interfaces …. Original signatories to this MOU were: the NMFS Northeast Fisheries Science Center, Bedford Institute of Oceanography – Dept. of Fisheries and Oceans, St. Andrews Biological Station – Dept. of Fisheries and Oceans, Gulf of Maine Ocean Observing System, Maine Department of Marine Resources, NOAA Coastal Services Center, USGS Woods Hole Field Center, and the Stellwagen Bank National Marine Sanctuary. The Partnership has held two meetings (April and December 2004) and two standing committees have met to address governance and technical issues. We are actively working with our partners to make this function as a "node" to other observing systems beyond the region as well as within the region. Toward this end, our effort has been directed toward establishing an interface with the central node that is to be hosted by GoMOOS.

15. Create regional and national alliances for education and outreach through collaboration and networking with other organizations engaged in coastal observing and ocean science education.

On March 22, 2004, representatives from COOA and 62 other agencies met in Charleston, South Carolina at the COOS, IOOS and Education Workshop. For two days the group generated plans to initiate an education network associated with the COOS/IOOS groups while developing a set of community recommendations for formal and informal education efforts. This meeting will be remembered by all as productive and timely. This meeting should be an annual event. In June, 2004, COOA and GoMOOS held a special session at the Summer ASLO meeting on The Educational Value of Coastal Ocean Observation Systems. This session was well attended and included such speakers as a high school teacher, members from the Mid Atlantic COSEE, and other research programs. In addition to the ongoing collaborative conversations with the COSEE (Center for Ocean Science Education Excellence) programs on the eastern seaboard, COOA and GoMOOS have been working with the New England COSEE to create two informal exhibits to be housed at the Seacoast Science Center in Rye, NH and the Woods Hole Exhibit Center in Woods Hole, MA. Through funding from the NE COSEE, we have provided a forum and facilitated the brainstorming process that will ultimately result in the creation of compelling informal exhibits that will integrate ocean observation data and topics into their centers.

16. Develop education materials and curricula for teaching marine ecology that employ observing system data, and deliver these materials to teachers at summer workshops.

Denise Blaha and Amy Holt Cline authored a chapter entitled "When is Dinner Served? Predicting the Spring Phytoplankton Bloom in the Gulf of Maine" for the Earth Exploration Toolbook which was publicly released this fall after thorough review. The chapter provides step-by-step instructions for educators and students to investigate phytoplankton and their role in the Earth system, using data from both WebCOAST and GoMOOS. The chapter was reviewed by several of our own scientists and later by teachers and our collaborators at TERC and the Science Education Resource Center at Carleton College. The Earth Exploration Toolbook is a project funded by NSF to connect teachers with on-line sources of Earth science data. It is a collection in the National Science Digital Library (NSDL) and is a reviewed collection in the Digital Library for Earth Science Education (DLESE). The chapter was demonstrated at the Massachusetts State Association Meeting in October 2004, and was featured in the most recent newsletter put out by the Gulf of Maine Marine Educators Association.

In June 2004, we hosted our first annual Educator Institute jointly co-sponsored by our Center and GoMOOS. The theme of this year's Institute was "Linking the Ocean to the Classroom: Predicting Phytoplankton Blooms in the Gulf of Maine." Twenty teachers from Maine to Virginia came to UNH to learn about how and why scientists study phytoplankton blooms in the Gulf of Maine. A full program included lectures by scientists Neal Pettigrew, Janet Campbell, Annette DeCharon, David Townsend, and Ru Morrison; a hands-on computer tutorial on satellite imagery using ImageJ, a trip aboard the R/V Gulf Challenger, and a lecture by Jonah Rosenfield, a high school teacher who has successfully integrated oceanographic buoy data into his environmental science classroom for the past 3 years. The group will return to UNH in March 2005 for a follow-up meeting.

17. Develop a better understanding of who the coastal resource managers are in COOA's region, what their local needs are, and develop products specifically tailored to meet their needs.

In collaboration with Josie Quintrell from GoMOOS, we have held several meetings with fisheries and coastal resource managers. In June 2004, we visited Massachusetts Coastal Zone Managers in Boston to explore ways that we might serve their needs. In September, GoMOOS and COOA hosted a meeting that brought together modelers, observationalists, and coastal resource managers to ask whether current models will meet the information needs of the managers, and whether observations will meet the data needs of the models. In December 2004, we met with Maine and New Hampshire coastal resource managers at the Wells National Estuarine Research Reserve. A follow-up one-day workshop with NH Department of Environmental Services is being organized by Brian Smith of the Great Bay Research Reserve and planned for early February. Plans for developing products to meet the needs of resources managers will be described in our Approach section.

18. Support graduate student fellowships in fields related to the mission of COOA.

Two graduate students have been supported with Center-sponsored fellowships administered by the UNH Marine Program under the direction of Jonathan Pennock. Brian Ortman matriculated into a PhD program in Zoology under the direction of Dr. Ann Bucklin. Brian's dissertation research topic is *Molecular systematic assessment of gelatinous zooplankton in the Gulf of Maine region*. This effort will provide baseline molecular systematic and population genetic data for gelatinous zooplankton occurring in the Gulf of Maine. Their long-term goal is to facilitate a comprehensive, global scale gelatinous zooplankton molecular database, which will provide an accurate assessment of biodiversity and assist future investigations into the systematics and molecular ecology of these species.

Ben Galuardi matriculated into a MS program in Zoology under the direction of Dr. Molly Lutcavage. Galuardi's thesis research will help determine the best estimates of migration paths of Atlantic bluefin tuna from data returned by popup satellite archival tags attached to the fish. He will examine several analytical approaches for using satellite data to optimize light-based geolocation estimates returned by the tags. This information can then be combined with remote sensing data and other oceanographic information to reduce geolocation errors and improve our understanding of Atlantic-wide movements of these highly migratory fish.

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